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Title: DEVELOPMENT AND EVALUATION OF A NEUTRON-PHOTON SHIELD FOR TRANSURANIC WASTE CONTAINERS

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Los Alamos
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DEVELOPMENT AND EVALUATION OF A NEUTRON-PHOTON SHIELD FOR TRANSURANIC WASTE CONTAINERS

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SUMMARY

The Los Alamos National Laboratory (LANL) Operational Health Physics Group in conjunction with the Nuclear Materials Technology Division Waste Management Group has developed a wrap-around shield for use with 55-gallon (0.208 cubic meter) drums containing transuranic (TRU) waste.

The shield or "drum cover" as it is called, is innovative in its ability to shield both neutron and gamma photons associated with TRU waste. The shielding materials are comprised of a 0.275-inch (7mm) thick sheet of borated polyurethane for neutrons, and two sheets of composite lead vinyl fabric (equivalent to 0.35 mm of lead) for shielding photons.

The drum covers have proven their relative effectiveness. Shielding tests have shown that the drum covers are highly effective in attenuating photons and are somewhat effective for shielding neutrons. Total (neutron and photon) radiation reduction for actual TRU drums has been as high as 87%.

I. BACKGROUND

The operation of the Plutonium Facility in Technical Area-55 at Los Alamos National Laboratory results in the generation of transuranic (TRU) waste. TRU waste refers to waste materials containing elements with atomic numbers greater than 92 containing more than 100 nCi (3.7 kBq) of alpha emitting TRU per gram of waste with a half-life of greater than 20 years. While the waste is not intensely radioactive, it must be less than 200 mR/hr (2 mGy/hr) on contact with the container to be disposed of as contact-handled TRU waste.

At the LANL Plutonium Facility, TRU waste drums are prepared for transport for ultimate disposal at the Waste Isolation Pilot Plant (WIPP) the underground TRU waste repository near Carlsbad, N.M. The NMT Waste Management and Environmental Compliance Group (NMT-7) works to characterize, prepare, package and temporarily store 55-gallon TRU waste drums.

The group in the course of their work will occasionally encounter TRU waste drums with higher than usual radiation levels. NMT-7 shields these drums to reduce the radiation dose rates to As Low As Reasonably Achievable (ALARA). Thus, the shielding helps reduce their personnel radiation doses.

Following an unsuccessful search to find an existing TRU drum shield the group decided to develop its own shield.

The NMT-7 personnel held a shield design meeting with the facility Operational Health Physics Group (ESH-1) and a local product vendor, Southwest Quality Suppliers, LLC of Albuquerque, N.M.

The waste management personnel provided design goals for the shield. These goals included:

- effectively shield neutrons and photons
- be easy to install and remove
- have a separate shielded lid for the top of the drum
- a Velcro™ strap and cam belt buckle fasteners for tightening the shield around the drum
- provide a contamination resistant durable outer layer that is easy to decontaminate
- be a manageable weight so that if necessary one person could install the shield
- provide a gap at the top so as not to obstruct the lid locks
- provide a clear pouch for easy viewing of drum paperwork

Radiation protection personnel specified shielding materials and capabilities for the radiation typically encountered in TRU waste. The shielding material and its thickness were design issues because a good photon shield is usually a poor neutron shield and vice versa. Although each TRU drum is unique and has its own assay for its radionuclide content it can be characterized by typical neutron and gamma photon radiation.

In the case of TRU waste, the neutrons are mainly from spontaneous fission. The photons are low-energy x-rays or gamma photons typically bounded by the 60 keV emission from the buildup of Americium-241 (^{241}Am) produced by decay of ^{241}Pu.

Following initial design discussions, the product vendor procured materials, fabricated and delivered a prototype drum cover.

II. THE DRUM COVER DESIGN

The shield material is encased in a waterproof easy-to-clean jacket of yellow Herculite™ 80. The drum cover wraps around 55 gallon drums and is cinched tight using Velcro™ straps and two cam tightened buckle belts. The drum cover includes a lid comprised of the same shield materials.

The shielding consists of two materials, one for neutrons and one for photons.

The neutron shield is made of 0.275-inch (7mm) thick sheet of borated polyurethane material. Thermo Reax™ makes the material and it is a product known as Borated FLEX Panel No. 227a. This material is 9-weight percent boron (5.8 x10^{21} atoms/cc) and has hydrogen content of 4.7x10^{22} atoms/cc. This rubber like material is strong, flexible and self-extinguishing when exposed to flame.

The photon shielding consists of two 0.175 mm sheets of composite lead vinyl fabric that is equivalent to 0.35 mm of lead. One sheet of vinyl is glued to each side of the FLEX Panel material. Figure 1 shows the layers of the shield.

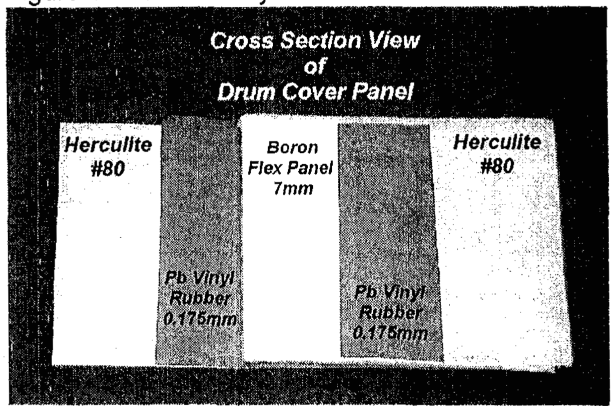

Figure 1

Figure 2 shows the prototype drum shield installed on a 55-gallon TRU drum. The drum cover measures 35 inches (89 cm) high by 80 inches (203 cm) in length and weighs 50 pounds (110 kg). The removable lid is 26 inches (66 cm) in diameter with 6-inch (15 cm) side flaps and weighs 19 pounds (42kg).

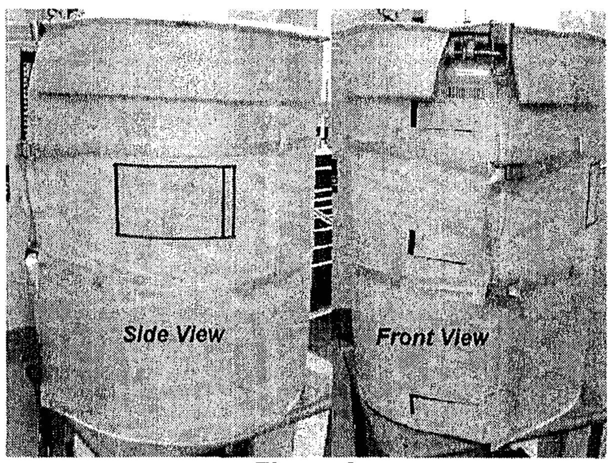

Figure 2

The prototype was then tested and refined based on user feedback and radiation shielding tests that were conducted at the LANL Plutonium Facility.

III. DRUM COVER TESTING

Three separate tests were performed to evaluate the shielding effectiveness of the drum shield.

The tests were performed based on simplified neutron attenuation methods using applied radiation protection techniques and field instruments. This approach was used to obtain rough estimates of expected doses to evaluate performance of the shield. Complex neutron shielding analysis is beyond the scope of this paper. Transport theory and Monte Carlo computer techniques remain as a follow-up to this study.

A. Test 1 Neutron Shielding

This test used a 55 gallon drum containing a number of ^{239}PuBe neutron sources packed in storage tubes in the center of the drum surrounded by more than seven inches (18 cm) of high density polyethylene. Four neutron instruments were used to measure neutron intensity in fixed locations. The active instruments were a high sensitivity polyethylene moderated ^{3}He counter tube known as the SWENDI-II made by Thermo Eberline™ and the N PROBE a neutron spectrometer based on a NE213 type liquid scintillator and a ^{3}He counter made by BTI™. The passive instruments included a plastic track etch detector (TED) and a solid-state neutron sensitive pocket dosimeter called the PDM-303 made by ALOKA™. Table 1 provides a summary of the results.

Table1. Neutron Shielding Results

Neutron Instrument	Unshielded (mrem/hr)	Shielded (mrem/hr)	Ratio
SWENDI-II	3.02	2.45	0.81
N Probe	1.44	1.20	0.83
PDM-303	3.57	2.58	0.72
TED	3.59	2.46	0.69

The attenuation factor is the ratio of the shielded dose rate to the unshielded dose rate. A ratio of 0.81 equates to a 19% reduction.

B. Test 2 Photon Shielding

Test 2 used x-rays from a standard diagnostic x-ray machine (General Electric™ Model DXD 350). The system consisted of a single-phase x-ray generator equipped with a tungsten target.

Exposure measurements to determine percent transmission through the shield were made on G plus medical x-ray film and standard film cassette. A small sample shield measuring 4 inches x 8 inches (10 cm x 20 cm) was placed over x-ray film at a distance of 40 inches (102 cm) from the x-ray source. The x-ray setting was 80 kVp, 100 mA and 1/20 sec. This setting was selected to match the x-ray spectrum that is characteristic of the TRU waste drums. The shielded film was then exposed and developed to determine the degree of effectiveness of the shield.

The exposed film was recognized by the degree of blackness of the film. Thus, where the film is the lightest is where the most shielding was provided.

Four test films where developed. All four were light under the shield sample. This indicated effective shielding. A quantitative reading of the film was made using an optical densitometer. Densitometer readings for the shield sample indicated an optical density of 1.1 that corresponds to a percent transmission of less than 10% (or attenuation of greater than 90%).

Transmission through the shield is equal to the ratio of the radiation exposure from the source with the shield in place (shielded) to the radiation exposure from the source without the shield (unshielded). Confirmation of the optical density readings was done using lithium fluoride type thermoluminescent dosimeter (TLD) chips placed in the x-ray beam above and below the shield sample.

TLD results shown in Table 2 confirmed the shield effectiveness indicating an average transmission factor (ratio) of 0.1 or attenuation of greater than 90% reduction.

Table 2. Photon Shielding Results

TLD reading	Unshielded	Shielded	Ratio
chip 1	1345	134	0.10
chip 2	1276	134	0.11
chip 3	1285	132	0.10
chip 4	1351	134	0.10

C. Test 3 Neutron and Photon Testing

The third test used a 55-gallon drum containing actual TRU waste with radionuclide contents being ^{239}Pu.

Unshielded and shielded radiation measurements were taken from the 55-gallon TRU waste drum on both the side and the top of the drum with the drum cover and lid installed. These measurements were made with standard radiation protection field instruments. The gamma photon measurements were made with a Thermo Eberline™ SHP 300A energy compensated low-level GM probe. The Thermo Eberline™ SWENDI-II measured neutron dose equivalent rates. Results are shown in Table 3.

Table 3. Neutron and Photon Shielding Results

Location of reading	Unshielded (mrem/hr)	Shielded (mR/hr)	Ratio
Top			
Photon	59.4	7.55	0.13
Neutron	0.33	0.27	0.82
Total	59.7	7.88	0.13
Side			
Photon	105.2	13.6	0.13
Neutron	0.24	0.21	0.87
Total	105.4	13.8	0.13

These measurements indicated a 13% to 18% reduction in neutron dose equivalent rates and an 87% reduction in the photon absorbed dose.

IV. RESULTS AND DISCUSSION

The Test 1 results in Table 1 show that the drum cover is partially effective in its ability to shield neutrons.

In Test 1, the neutron reduction ranged from 17% to 19% for the two active measurement instruments listed in Table 1. For the passive and solid-state type instruments the neutron reduction factors ranged up to 31%. However, these results are not as convincing when neutron energy spectrum issues are taken into account. The first two neutron instruments, the SWENDI-II and N PROBE have a relatively flat energy response over the range of energies emitted from the test source. The third and fourth instruments, the PDM-303 and TED significantly over-respond and under-respond respectively, for energies below 500 keV. Thus, we have less confidence in the attenuation factors calculated using the PDM-303 and TED.

Test 2 results show that the drum shield is highly effective in attenuating x-ray photons. A reduction factor greater than 90% is expected based on x-ray tests. This was based on an optical density (OD) of 1.1 resulting in a transmission of 8% (or conversely attenuation of 92%).

The TLD data provided a reduction factor ratio of 0.1 or a 90% reduction in transmitted photons.

The 80 kVp x-ray energy in Test 2 was selected to represent the predominant photon energies typical of TRU wastes. The photons in typical TRU wastes are usually bounded by energies below that of the 60 keV photon of the ^{241}Am that arises from the decay of ^{241}Pu.

Test 3 results were based on actual TRU drum readings that can be encountered in day-to-day use. It can be concluded that the drum shield will be effective for typical applications.

V. CONCLUSIONS

The drum cover neutron and photon shield capability successfully met the design goals of the NMT Waste Management Group. The drum covers are presently in use at TA-55. They are now routinely used as an ALARA tool for reducing personnel radiation exposures.

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